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CHAPTER 32

# PLANT RESIDUES AND POMACES

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## I. INTRODUCTION

The value of plant residues and pomaces as a source of protein meals is largely dependent on economic needs. In periods of high production and surpluses in any particular country it is difficult to justify the economic production of many of the possible products that can be made from the so-called wastes of the fruit and vegetable industries. On an international scale, however, the need for additional protein is always present, and production is never adequate. As a consequence, waste plant residues and pomaces are rarely found in many countries. Of course, as large-scale processing industries develop in more areas of the world, residues are bound to occur.

Just what is meant by the terms plant residues and pomaces? Whenever a fruit or vegetable is harvested for use as a human food or drink, only a part of the product is utilized. Often the quantity of the unused portion exceeds that of the usable portion. Furthermore, the so-called waste not only exceeds the food portion of the plant in quantity, it often contains a much greater amount of protein. These are the plant residues which will be discussed in this chapter. There will also be mention of the residues of coffee and cocoa.

## II. SOURCES OF VEGETABLE RESIDUES AND POMACES

### 1. Vegetable Wastes

#### *a. Field*

Many vegetable crops are harvested from the fields in nearly marketable conditions by machines especially equipped to perform digging and cutting operations. There has been a continued trend toward the use of these machines in the United States in the last ten years to minimize labor requirements. As a consequence, crops like beets, carrots, turnips, and parsnips come into the packing sheds with little waste. Instead the leaf and stem wastes or residues remain spread on the ground where they are allowed to wilt down to be plowed under as humus. A serious objection to this practice is that it tends to spread diseases or retain them in the same field for years. Rotation of crops is often practiced to combat the field-borne diseases, but many growers feel that harvesting of the whole plant with separation at a central packing shed would be preferable, if the waste portions could be utilized. Cover crops could be substituted as a source of humus.

### *b. Viner Stations*

Green pea and lima bean wastes occur in large quantities at viner stations which are located in centralized areas of the fields. In good dairy areas these viner wastes are ensiled and used as feed. In locations where they cannot be sold for feed the wastes are either spread on fields or allowed to rot in piles for later use as humus. Under these conditions they present serious problems because of odor and ground contamination.

### *c. Processing Plants*

Wastes from processing plants occur in the form of trimmings, peels, seeds, bean snips, and extractives from washing and blanching operations. Solid residues are collected by belts or by screening of wash waters and are usually carried by truck to disposal dumps or distributed in small piles as humus on adjacent fields. In this form they constitute a serious health menace in the neighboring communities. The wash and blanch water extractives present an even more serious disposal problem; it has been customary to flush this water into streams or rivers or into sewers if the plant is located in urban areas. Government controls are becoming increasingly rigid, and other methods of disposal are being required.

### *d. Tomato Pomace*

One of the major processing vegetables in the United States is the tomato; some 3¼ million tons of tomatoes were produced for processing in 1953. Some of the tomatoes were canned, but by far the largest quantity went into making of juice and juice products, i.e., catsup, paste, and purée. The residue from these operations consists of skins, seeds, trimmings, and liquor, or tailings as they are called in the industry. Their disposal has consisted primarily in dumping of solids in remote areas and flushing of liquid effluents into sewage plants or into streams and rivers, and has presented difficulties.

### *e. Quantity of Wastes*

The quantity of vegetable wastes available from the above-mentioned sources cannot be estimated accurately. In 1955 the production of vegetables in the United States for the fresh market was 10,289,800 tons, that for processing 6,142,900 tons, or a total of 16,432,700 tons. Morris *et al.* (*1*) and Morris (*2*) estimated waste in the United States from commercial vegetables producing primarily leafy wastes for the year 1944 as follows: Total production of sixteen vegetables for fresh market and processing was 3,401,398 tons. On the basis of information obtained from fresh market packing plants, processing plants, and trade organizations and publications, the total waste connected with the production of these sixteen vegetables was estimated to be 4,528,040 tons. If the same factor of 1.33 (tonnage of waste/tonnage of edible vegetable) were applied to the total estimated tonnage of vegetables produced in the United States in 1955, the waste from this production would amount to 21,855,491 tons. With an average moisture content of 88%, the dry matter in this tonnage of waste would be 2,622,658 tons; and with an average content of crude protein of 15% on a dry weight basis, the protein in the total production of vegetable wastes would amount to about 393,398 tons.

## 2. Citrus Residues

Citrus fruits, consisting primarily of oranges, grapefruit, lemons, limes, and tangerines, have become, within the last thirty years, one of the great agricultural commodities. The production of these five citrus fruits for 1953 in the United States was given as 194,990,000 boxes, with the weights per box ranging from 65 to 90 pounds. With an average weight of 80 pounds per box, this would amount to a production of 7.8 million tons of fruit in the United States.

In 1951 Owens *et al.* (*3*) stated that more than 2 million tons of citrus pulp, peel, and rag remained each year after citrus fruits were processed into juice, frozen concentrate, and sections. This waste material, like vegetable wastes, was formerly disposed of by spreading the solid waste on adjacent lands and flushing the liquid wastes in ponds, streams, lakes, or sewers. This procedure became so offensive that Government agencies found it necessary to develop other methods of disposal. As a result, 80 to 90% of citrus wastes are converted to useful products.

### 3. Coffee and Cocoa Residues*

#### a. Coffee

Of a total consumption of about 2 billion pounds of coffee beans in the United States, about 20% is converted into soluble coffee. This amounts to 200,000 tons of green beans or 190,000 tons of roasted coffee beans. In the process of making soluble coffee, 25 to 40% of the roasted bean is extracted, leaving 120,000 to 150,000 tons of residue on the dry weight basis.

#### b. Cocoa

The by-products obtained from the cocoa and chocolate manufacturing industry are cocoa shells and cocoa germs. On a world-wide basis, about 720,000 tons of cocoa beans are used annually in the manufacture of these two products. These provide about 70,000 tons of cocoa shells and 7000 tons of germs. The shells contain from ½ to 1% of the very valuable cocoa nibs, and the germs usually contain from 10 to 25% of cocoa nibs after mechanical separation.

## III. RECOVERY OF VEGETABLE WASTE MATERIALS

### 1. Vegetable Leaf Meals

A survey by the staff of the Eastern Regional Research Laboratory of the U.S. Department of Agriculture of eighty-three vegetable tissues for protein and vitamins indicated that certain of these tissues were sufficiently high in nutritive value and in content of potential industrial chemicals to warrant more intensive study. Table I shows the composition of many of the wastes. The leafy tissues of wastes from beets, broccoli, lettuce, lima beans, and peas are the most promising, since they occur in large amounts and have a high enough protein content. Other wastes could be used to supplement the supplies of total waste for a processing plant, but these would not support a commercial operation by themselves.

The major problems of vegetable waste utilization are to find a way to process the plant material as soon as possible after harvest and to work out a method for separation of the more valuable leafy tissue from the more fibrous stemmy portions. Dehydration in commercial-type dryers is the only practical method of preserving fresh vegetable tissues to obtain high-quality protein meals. This may be accomplished by a process of fractional drying in which the fresh material is dried in a high-velocity stream of air at temperatures ranging from 250° to

* The material on these commodities was largely provided by Dr. A. Kentie, Technical Director, The Nestlé Company, Inc., Fulton, New York.

TABLE I

COMPOSITION OF TYPICAL DRIED VEGETABLE TISSUES

| Vegetable tissue fraction | Moisture | Proportion of whole top | | Chemical analyses[a] (moisture-free basis) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fresh basis | Dry basis | Crude[b] protein | Crude fiber | Ether extract | Carotene | Riboflavin |
| | % | % | % | % | % | % | p.p.m. | p.p.m. |
| Beet | | | | | | | | |
| Leaf | 90.4 | 52.6 | 54.2 | 27.3 | 6.0 | 6.2 | 568 | 21.5 |
| Stem | 91.0 | 47.4 | 45.0 | 13.6 | 14.7 | 1.7 | 48 | 7.4 |
| Broccoli | | | | | | | | |
| Leaf | 81.5 | 36.4 | 53.7 | 35.9 | 7.6 | 8.5 | 803 | 25.6 |
| Petiole and stem | 91.0 | 63.6 | 46.3 | 19.0 | 16.5 | 3.3 | 81 | 8.5 |
| Cabbage, leaf | — | — | — | 22.4 | 8.2 | 4.7 | 295 | 9.9 |
| Carrot | | | | | | | | |
| Leaf | 79.0 | 51.2 | 65.1 | 27.9 | 10.1 | 5.6 | 295 | 15.7 |
| Stem | 88.1 | 48.8 | 34.9 | 11.1 | 19.3 | 5.4 | 41 | 8.1 |
| Cauliflower | | | | | | | | |
| Leaf | — | — | — | 26.6 | 9.5 | 4.1 | 185 | 23.2 |
| Petiole | — | — | — | 17.1 | 17.3 | — | 28 | 9.2 |
| Celery | | | | | | | | |
| Leaf | 87.0 | — | — | 27.2 | 3.5 | 6.9 | 352 | 18.4 |
| Stalk | 94.0 | — | — | 12.6 | 14.3 | 3.1 | 11 | 5.7 |
| Collard | | | | | | | | |
| Leaf | — | — | — | 27.3 | 6.8 | 5.3 | 251 | 15.8 |
| Petiole | — | — | — | 14.8 | 9.8 | — | 28 | — |
| Corn, sweet, leaf | — | — | — | 17.1 | 26.6 | 5.5 | 578 | 5.5 |
| Kale | | | | | | | | |
| Leaf | 77.3 | 57.5 | 63.3 | 29.4 | 7.6 | 5.8 | 340 | 21.0 |
| Petiole and stem | 82.3 | 42.5 | 36.7 | 16.2 | 10.0 | 4.2 | 21 | 8.0 |
| Lima | | | | | | | | |
| Bean | 61.6 | 20.8 | 28.1 | 23.9 | 6.0 | 3.7 | 3 | 2.4 |
| Leaf | 67.7 | 15.8 | 18.0 | 19.4 | 10.5 | 6.4 | 465 | 12.4 |
| Pod | 77.1 | 25.8 | 20.9 | 10.0 | 37.8 | 3.0 | 14 | 3.7 |
| Stem | 74.3 | 36.9 | 33.5 | 9.2 | 40.1 | 2.2 | 36 | 3.9 |
| Parsnip | | | | | | | | |
| Leaf | — | — | — | 22.9 | 8.0 | 5.0 | 232 | 11.9 |
| Stem | — | — | — | 6.0 | 17.2 | — | 4 | 4.3 |
| Pea | | | | | | | | |
| Leaf | 65.7 | 12.3 | 14.1 | 21.7 | 14.4 | 5.8 | 346 | 26.2 |
| Pea | 80.1 | 22.4 | 19.9 | 28.8 | 9.2 | 1.7 | 4 | 7.8 |
| Pod | 84.0 | 35.5 | 25.2 | 14.1 | 18.4 | 1.2 | 23 | 7.8 |
| Stem | 67.4 | 29.9 | 41.0 | 11.0 | 39.2 | 2.3 | 47 | 9.6 |
| Rutabaga | | | | | | | | |
| Leaf | 82.2 | 36.1 | 51.4 | 31.5 | 6.3 | 6.5 | 257 | 20.9 |
| Stem | 90.5 | 63.6 | 48.4 | 18.5 | 14.9 | — | 13 | 8.5 |
| Turnip | | | | | | | | |
| Leaf | 87.3 | 46.8 | 61.9 | 30.9 | 7.5 | 4.4 | 473 | 20.3 |
| Stem | 93.1 | 53.2 | 38.2 | 18.0 | 10.3 | — | 54 | 11.6 |
| Spinach | | | | | | | | |
| Leaf | 90.4 | 45.1 | 54.7 | 32.0 | 6.8 | 4.1 | 314 | 14.6 |
| Stem | 93.5 | 55.0 | 45.3 | 22.5 | 9.3 | — | 120 | 8.5 |

[a] E. G. Kelley, *Yearbook Agr. U.S. Dept. Agr.* 843 (1950–1951).

[b] Nitrogen × 6.25.

300°F. The thin leaf blades dry more rapidly than the thicker petiole and stem parts of the waste; the dry leaf blade is brittle, and when it is subjected to breaking and screening action it can be separated from the partly wet and tougher stemmy material (*4*).

Table II shows the yield and composition of six leaf meals prepared from vegetable wastes (*5*).

More detailed information on the yield and composition of fifteen leaf wastes together with details of drying procedures using both tray and continuous-belt dryers can be obtained by reference to the work

TABLE II

AVERAGE YIELD AND COMPOSITION OF LEAF MEALS FROM VEGETABLE WASTES[a]

| Vegetable waste | Moisture | Yield[c] | Composition (dry basis)[b] Crude[d] protein | Crude fiber | Ether extract | Carotene | Riboflavin |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | p.p.m. | p.p.m. |
| Beet tops | 92.0 | 5.6 | 29.6 | 6.2 | 7.6 | 460 | 18.4 |
| Broccoli | 88.5 | 6.6 | 35.7 | 6.1 | 9.5 | 460 | 24.7 |
| Carrot tops | 80.7 | 9.6 | 18.0 | 8.5 | 5.1 | 158 | 10.1 |
| Lima bean leaves | 73.8 | 17.8 | 21.2 | 6.9 | 6.0 | 297 | 14.0 |
| Pea vines | 81.5 | 9.7 | 14.6 | 18.8 | 4.1 | 85 | 16.8 |
| Rhubarb | 88.6 | 10.7 | 27.4 | 6.8 | — | 285 | 7.0 |

[a] D. A. Colker and R. K. Eskew, *U.S. Dept. Agr., Bur. Agr. and Ind. Chem.* AIC-76, 4 (1945).

[b] E. G. Kelley, *Yearbook Agr. U.S. Dept. Agr.* 843 (1950–1951).

[c] On the basis of fresh material.

[d] Nitrogen × 6.25.

of Kelley (*6*). The use of rotary alfalfa dryers for the fractional drying of vegetable wastes has been described by Aceto *et al.* (*7*).

Feeding studies on poultry were carried out with the vegetable leaf meals in which they were used as a source of carotene (vitamin A) or riboflavin rather than as a protein source (*8*). Only in one experiment with solvent-extracted broccoli leaf meal was the meal used as the source of the protein in broiler diets (*9*). In this particular feeding trial, growth was maintained on the broccoli meal, but the addition of soybean oil meal to the leaf meal produced more rapid growth.

The quantitative determination by microbiological methods of the content of the ten essential amino acids in vegetable leaf meals revealed that most of the leaf meals were similar in over-all composition and that they contained the essential amino acids (*10*). (See Table III.) Determination of methionine in the leaf meals required special

TABLE III
AMINO ACIDS IN LEAF MEALS[a]

| Source | Crude protein | Histidine | Arginine | Lysine | Leucine | Iso-leucine | Valine | Methi-onine[b] | Threo-nine | Phenyl-alanine | Trypto-phan |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % | % |
| Beet | 24.3 | 1.3 | 4.1 | 5.4 | 6.4 | 4.2 | 5.1 | 1.7 | 3.8 | 5.8 | 1.2 |
| Broccoli | 41.0 | 1.5 | 4.8 | 4.5 | 6.4 | 3.2 | 4.5 | 1.8 | 3.3 | 6.0 | 1.4 |
| Carrot | 19.6 | 1.9 | 4.3 | 4.5 | 7.1 | 4.5 | 5.5 | 1.7 | 4.4 | 6.5 | 1.4 |
| Celery | 23.2 | 1.5 | 4.0 | 2.4 | 6.8 | 3.9 | 4.8 | 2.2 | 3.4 | 4.5 | 1.3 |
| Corn | 19.4 | 1.3 | 3.9 | 3.2 | 6.9 | 3.6 | 4.8 | 2.8 | 3.3 | 5.4 | 1.3 |
| Kale | 24.7 | 1.6 | 5.1 | 3.1 | 6.5 | 3.4 | 4.6 | 0.9 | 3.5 | 4.4 | 1.1 |
| Lima bean | 16.9 | 1.3 | 4.2 | 3.6 | 6.6 | 3.6 | 5.0 | 1.2 | 4.0 | 7.0 | 1.4 |
| Pea | 23.6 | 1.6 | 4.6 | 4.9 | 7.8 | 4.4 | 5.7 | 1.0 | 4.4 | 6.0 | 1.5 |
| Rhubarb | 26.1 | 1.9 | 4.7 | 5.4 | 8.4 | 4.0 | 5.3 | 1.0 | 4.0 | 6.1 | 1.6 |
| Spinach | 25.7 | 1.3 | 4.4 | 4.7 | 6.8 | 3.6 | 5.0 | 2.3 | 3.9 | 4.7 | 1.1 |
| Turnip | 23.9 | 1.4 | 4.5 | 3.0 | 6.8 | 3.9 | 4.8 | 2.2 | 4.0 | 5.3 | 1.3 |
| Range | 16.9–41.0 | 1.2–3.9 | 3.9–5.2 | 2.4–5.4 | 6.4–8.4 | 3.2–4.6 | 4.5–5.8 | 0.9–2.8 | 3.3–4.5 | 4.4–7.0 | 1.1–1.6 |
| Other leaf meals[c] | | | | | | | | | | | |
| Alfalfa | 18.1–19.4 | 1.2–2.1 | 3.1–4.3 | 3.6–4.9 | 6.2–6.6 | 3.6–5.2 | 4.1–4.4 | 0.2–1.4 | 2.2–3.6 | 4.1–4.6 | 1.0–1.4 |
| Grass | 19.4 | 3.1 | 6.7 | 7.2 | 13.4 | 9.3 | 10.3 | 2.1 | 6.7 | 8.8 | 2.1 |
| Ryegrass | 12.5 | 2.2 | 5.4 | 3.3 | 6.2 | 4.0 | 5.0 | 1.1 | 3.9 | 3.0 | 1.3 |

[a] E. G. Kelley and R. R. Baum, *J. Agr. Food Chem.* 1, 680 (1953); calculated on the basis of 16% nitrogen.
[b] Two-hour hydrolysis.
[c] R. J. Block and D. Bolling, "Amino Acid Composition of Proteins and Foods," 2nd ed. Charles C Thomas, Springfield, Illinois, 1951.

TABLE IV

AMINO ACIDS IN PROTEIN CONCENTRATES[a,b]

| | Leaf protoplasts | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | Crude protein | Histidine | Arginine | Lysine | Leucine | Isoleucine | Valine | Methionine | Threonine | Phenylalanine | Tryptophan |
| | % | % | % | % | % | % | % | % | % | % | % |
| Beet | 40.9 | 1.9 | 5.9 | 5.6 | 8.6 | 5.5 | 6.3 | 1.6 | 4.9 | 6.5 | 1.7 |
| Broccoli, fat-free | 78.2 | 1.8 | 5.2 | 5.3 | 8.9 | 4.7 | 5.9 | 1.8 | 4.4 | 7.8 | 2.3 |
| Carrot | 27.0 | 2.0 | 6.9 | 5.5 | 10.7 | 6.3 | 7.2 | 1.8 | 6.1 | 8.4 | 2.2 |
| Lima bean | 48.4 | 1.5 | 5.5 | 3.8 | 8.0 | 4.7 | 5.6 | 1.2 | 4.6 | 7.4 | 1.7 |

| | Leaf proteins extracted with formic acid | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | Histidine | Arginine | Lysine | Leucine | Isoleucine | Valine | Methionine | Threonine | Phenylalanine |
| | % | % | % | % | % | % | % | % | % |
| Broccoli | 2.2 | 6.0 | 5.5 | 9.2 | 5.3 | 6.4 | 2.0 | 5.0 | 7.5 |
| Carrot | 2.1 | 5.7 | 5.4 | 10.6 | 5.5 | 7.0 | 3.4 | 5.0 | 7.7 |
| Lima bean | 1.9 | 5.7 | 5.2 | 9.1 | 5.2 | 5.9 | 2.2 | 4.7 | 7.0 |
| Pea vine | 1.8 | 5.4 | 5.8 | 8.7 | 5.1 | 6.1 | 1.8 | 4.5 | 6.7 |
| Rhubarb | 2.4 | 6.3 | 5.4 | 9.8 | 5.0 | 6.6 | 2.1 | 4.6 | 6.9 |
| Rutabaga | 1.7 | 5.4 | 5.6 | 7.2 | 4.7 | 6.0 | 1.6 | 4.2 | 5.8 |
| Spinach | 1.8 | 5.4 | 5.8 | 8.2 | 4.2 | 6.0 | 1.8 | 4.6 | 5.8 |

[a] E. G. Kelley and R. R. Baum, *J. Agr. Food Chem.* 1, 680 (1953).

[b] Calculated on the basis of 16% nitrogen.

hydrolysis conditions, since the presence of carbohydrates caused some losses in the normal 10-hour acid hydrolysis. A two-hour hydrolysis gave more satisfactory results.

Partially purified proteins were made from vegetable leaves by a fermentation procedure and also by formic acid extraction. Table IV shows the protein and amino acid contents for some of the vegetable leaf protein concentrates. In Table V the amino acid contents of the meals and the protein concentrates are compared. The amino acid content of the leaf meals is about 25% lower than in the protein concentrates when the comparison is made on the basis of total nitrogen

TABLE V

COMPARISON OF AVERAGE AMINO ACID CONTENTS OF THREE LEAF MEALS AND THEIR PROTEIN CONCENTRATES[a]

| Leaf preparation[b] | Histidine | Arginine | Lysine | Leucine | Isoleucine | Valine | Methionine | Threonine | Phenylalanine | Tryptophan |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % |
| Meals | 1.4 | 4.4 | 4.2 | 6.7 | 3.8 | 5.0 | 0.48 | 3.9 | 6.5 | 1.4 |
| Protoplasts | 1.8 | 5.9 | 4.9 | 9.2 | 5.2 | 6.2 | 1.6 | 5.0 | 7.9 | 2.1 |
| Formic acid extract | 2.1 | 5.8 | 5.4 | 9.6 | 5.3 | 6.4 | 2.5 | 4.9 | 7.4 | — |

[a] E. G. Kelley and R. R. Baum, *J. Agr. Food Chem.* **1**, 680 (1953); calculated on the basis of 16% nitrogen.

[b] Broccoli, carrot, and lima bean.

(Kjeldahl N). Recent studies on cabbage leaves have revealed that as much as 50% of the total nitrogen is non-protein nitrogen.*

Although the vegetable leaf meals are good sources of protein for poultry and livestock, it is doubtful that they could compete with oilseed meals. They do, however, contain other valuable ingredients which put them on a competitive basis with other leaf meal feed supplements. Carotene (provitamin A), and xanthophyll, a yellow pigment desired in poultry feeds for flesh coloring, are present in considerable amounts, and these can be used either in the form of the dehydrated leaf meal or as solvent-extracted oils. Poultry feeding trials proved that these two substances could be utilized effectively from the leaf meals and that the extracts also made excellent feed supplements. Wall and Kelley determined content of tocopherol (vitamin E) (*11*) and leaf sterols in various leaf meals (*12*), and Wall (*13*) separated a number of fractions of these materials by molecular distillation. Since the leaf meals were prepared from fresh material under carefully controlled temperature

* E. G. Kelley, S. Krulick, R. R. Baum, R. M. Zacharius, and J. J. McGuire, personal communication.

conditions, a high quality chlorophyll salt could be prepared from most of them (*14*).

Petiole and stem residues remaining after preparation of vegetable leaf meals by the fractional drying process are of lower value, and their economic recovery is uncertain. They can be dried further and ground to provide bulk for feed mixtures, since they often do have appreciable protein content. They also contain sufficient fiber to be used for mulch or litter at a price competitive with those of peat moss or shell products. They are excellent as a source of humus for soil rebuilding.

## 2. Tomato Pomace

The recovery of tomato pomace has been studied by Edwards *et al.* (*15*). The process requires additional steps other than the drying described for leafy wastes. Because of their semiliquid state it is necessary first to obtain a high solids fraction from the chopped culls and trimmings by passing them through a cyclone. The tailings from the cyclone are added to similar tailings from juice-making cyclones and pressed in a continuous rotary press to yield a press cake and a dilute liquor. The press cake, of about 63% moisture content, is dried in rotary alfalfa dryers under suitable conditions.

TABLE VI

ANALYSIS OF DRIED TOMATO PRESS CAKE[a]

| Ingredient | Press cake | Press cake with added concentrate |
|---|---|---|
| | % | % |
| Moisture | 8.0 | 8.0 |
| Crude protein[b] | 22.5 | 21.0 |
| Fat | 14.2 | 9.8 |
| Fiber | 29.6 | 21.9 |
| Ash | 3.3 | 5.9 |
| Nitrogen-free extract | 22.4 | 33.4 |

[a] P. W. Edwards, R. K. Eskew, A. Hoersch, Jr., N. C. Aceto, and C. S. Redfield, *Food Technol.* 6, 383 (1952).

[b] Nitrogen × 6.25.

Since the liquid waste from the presses and that from the waste cyclone still contain about 5% solids, these are concentrated by evaporative procedures to about 30% solids. This thick liquid can then be added in certain proportions to the dried press cake and the combined product passed again through the rotary dryer.

Table VI shows the analysis of the dried press cake, alone and plus concentrate.

Dried tomato pomace is made in commercial quantities for use in dog foods and in feeds for fur-bearing animals. It is largely made from the press cake alone because of the lower cost of production. When effluents become a more costly sewage disposal problem they can be incorporated into the dried pomace.

About 2 to 3% of the dried press cake, added to dry-type feeds, is valuable for the prevention of diarrhea in dogs and mink. Broilers utilized dried tomato press cake more efficiently than they did alfalfa meal, and tomato press cake and concentrate were superior as a growth promoter to wheat middlings when used as a replacement at a 5% level. As noted earlier, 3¼ million tons of tomatoes were processed in the United States in 1953. For every million tons of tomatoes there would result about 123,800 tons of recoverable waste containing 11,300 tons of solids. There exists a potential for production of about 36,000 tons of dried pomace, but at present (1957) only a fraction of this amount is being made.

### 3. Citrus Pomace

Von Loesecke has reviewed and summarized much of the recent work on citrus wastes (*16*). There is also a handbook of the chemistry and technology of the citrus industry (*17*). Most of the following description of the recovery of various products from citrus wastes has been taken from these two publications. Information on the use of citrus fruit and waste for feeding dairy cattle in Israel is given by Volcani (*17a*).

In 1949 there was in the United States an estimated 3½ million tons of solid citrus waste and about 4 billion gallons of liquid effluents. Probably about 90% of the solid waste is dried yearly for feeds, and considerable quantities of the liquid effluents are converted to feed, molasses, and other by-products. Solid wastes consist of cannery wastes such as peel, rag (core plus segment membranes), and seed, screening from citrus pulp-drying effluents, sludge from peel oil preparations, residues from plants producing citric acid and pectins, and still slops. The liquid wastes are largely cannery effluents, pulp drying plant and distillery effluents, and effluents from citrus molasses and peel oil plants.

Table VII shows the analysis of several types of solid citrus cannery waste.

The solid wastes have been utilized most successfully for the preparation of dried citrus pulp for cattle and swine feeds. The method of preparation of this dried pulp is essentially the same in the numerous drying plants making this material on a commercial scale. Some varia-

TABLE VII

ANALYSES OF CITRUS CANNERY WASTE[a]

| Constituent | Florida grapefruit Peel | Florida grapefruit Rag | California grapefruit, peel and rag | Israel grapefruit, peel[b] | Lemon, peel and rag |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| Total solids | 16.71 | 15.60 | 22.02 | 17.9 | 16.17 |
| Ash | 0.74 | 0.75 | 0.70 | 0.70 | 0.82 |
| Volatile oil | 0.43 | — | 0.56 | — | — |
| Acid, as citric | 0.74 | 0.63 | 0.43 | — | 0.60 |
| Crude fiber | 1.71 | 1.44 | 2.00 | 1.9 | 2.73 |
| Crude protein[c] | 1.13 | 1.06 | 1.63 | 1.2 | 1.56 |
| Crude fat (ether extract) | 0.28 | 0.16 | 0.23 | 0.3 | — |
| Total sugar (as invert) | 6.35 | 6.30 | 8.68 | — | — |
| Pentosans | 0.83 | 0.44 | 1.31 | — | 2.61 |
| Pectin (calcium pectate) | 3.10 | 3.56 | 3.93 | — | — |
| Naringin | 0.40 | 0.10 | 0.63 | — | — |

[a] Except where noted, the data are from H. W. Von Loesecke, *Ind. Eng. Chem.* **44**, 476 (1952).

[b] A. Bondi and K. Mayer, *Empire J. Exptl. Agr.* **10**, 93 (1942).

[c] Nitrogen × 6.25.

tions occur in dryer design; both direct-fired and steam tube dryers are in common use. The nature of the presses used in the preliminary removal of water may vary, but in all instances the end result is about the same.

A general description of the method follows: Lime (0.3 to 0.5%) is added to the wet waste; it is then shredded or chopped in a cutting mill and slowly mixed and aged in a pug mill. The lime is added to neutralize the fruit acids and combine with the fruit pectins to form calcium pectate which aids in the pressing operation that follows. The material is pressed in continuous presses as dry as possible and fed to the dryers in a uniform manner. With proper control of drying rate and temperature, a fluffy, light-colored feed is produced in a yield of about 1 ton of feed from 10 tons of waste. This material is bagged and sold under numerous trade labels as dried citrus pulp. In 1955 over 300,000 tons of this product were produced in Florida. Texas and California also produce considerable tonnages. The market value of this product is in excess of 12 million dollars per year.

Table VIII shows a typical analysis of dried grapefruit waste.

Dried citrus pulp is used primarily as a carbohydrate concentrate. It is low in content of crude protein, fiber, and fat and high in content of nitrogen-free extract. Neal *et al.* (*18*) found a high coefficient of

TABLE VIII

Analysis of Dried Grapefruit Waste[a]

| Constituent | Content | Constituent | Content |
|---|---|---|---|
| | % | | % |
| Moisture | 7.54 | Naringin | 1.52 |
| Ash | 6.00 | Potassium and sodium chlorides | 1.79 |
| Protein[b] | 6.49 | Silica | 0.23 |
| Crude fat | 5.46 | Iron and aluminum ($Al_2O_3$ + $Fe_2O_3$) | 1.94 |
| Crude fiber | 14.06 | Magnesium (Mg) | 0.34 |
| Pentosans | 14.35 | Calcium (Ca) | 1.63 |
| Sucrose (non-reducing sugars) | 9.18 | Phosphates ($P_2O_5$) | 0.26 |
| Reducing sugars (as invert) | 2.82 | Sulfur (S) | 0.10 |
| Total sugars | 11.00 | Chlorides ($Cl_2$) | 0.05 |
| Pectin (alcohol precipitate) | 18.20 | | |

[a] H. W. Von Loesecke, *Ind. Eng. Chem.* **44**, 476 (1952).

[b] Nitrogen × 6.25.

digestibility for the whole dried product amounting to 83 and 81% for grapefruit and orange pulp, respectively; the nitrogen-free extract fraction is from 88 to 92% digestible. The crude protein fraction was lower in digestibility, showing only 24.8 and 36.6% digestible material in the dried grapefruit and orange pulps, respectively. Jones *et al.* (*19*) showed that a diet containing 25% dried citrus pulp was satisfactory for growth of beef cattle. Arnold *et al.* (*20*) found the citrus pulp equal to dried beet pulp as a bulky carbohydrate feed for dairy cattle. Kirk and Crown (*21*) found that the citrus pulp was less satisfactory as a feed for swine, and Mehrhof and Rusoff (*22*) found that even 5% of the dried grapefruit pulp gave unfavorable results with young poultry, although pullets and laying birds apparently could utilize this feed to a greater extent without affecting their rate of growth or egg production.

Lyman *et al.* (*23*) have determined the content of crude protein and the ten essential amino acids in a sample of dried citrus pulp. (Table IX.) Townsley *et al.* (*24*) and Underwood and Rockland (*25*) have reported on the amino acids of citrus juices and proteins from chromatophores and other solid portions of citrus fruits.

### 4. Coffee Residues

The main by-product of coffee is the residue which is left after the water-extraction of coffee for the manufacture of soluble coffee. Water-extraction of ground roasted coffee beans removes 25 to 40% of the weight of the roasted coffee bean. This extract is dried and sold as

TABLE IX

AMINO ACID CONTENT OF CITRUS PULP[a]

| Amino acid | In pulp | In crude protein[b] |
|---|---|---|
| | % | % |
| Arginine | 0.28 | 4.81 |
| Histidine | 0.09 | 1.55 |
| Isoleucine | 0.18 | 3.10 |
| Leucine | 0.31 | 5.33 |
| Lysine | 0.20 | 3.44 |
| Methionine | 0.08 | 1.37 |
| Phenylalanine | 0.18 | 3.09 |
| Threonine | 0.18 | 3.09 |
| Tryptophan | 0.06 | 1.03 |
| Valine | 0.25 | 4.30 |

[a] C. M. Lyman, K. A. Kuiken, and F. Hale, *J. Agr. Food Chem.* **4**, 1008 (1956).
[b] Calculated on the basis of 16% nitrogen.

TABLE X

COMPOSITION OF COFFEE BEANS AND COFFEE GROUNDS[a]

| Analysis | Green | Roasted | Coffee grounds |
|---|---|---|---|
| | % | % | % |
| Moisture | 8.75 | 3.75 | 5.5 |
| Ash | 4.41 | 4.49 | 1.0 |
| Fat | 12.96 | 13.76 | 25.4 |
| Caffeine | 1.87 | 1.81 | 0.5 |
| Crude fiber | 20.70 | 14.75 | 38.7 |
| Protein | 9.50 | 12.93 | 10.59 |
| Water extract | 31.11 | 30.30 | — |
| Nitrogen | — | — | 2.4 |
| Lignin | — | — | 13.3 |
| Sugar | 7.62 | 1.31 | — |
| Dextrins | 0.86 | 1.31 | — |
| Tannic acid | 9.02 | — | — |

[a] Data on all but sugar, dextrins, and tannic acid are taken from W. H. Ukers, "All About Coffee," 2nd ed. Tea and Coffee Trade Journal Co., New York, 1935. The data on the others are from W. L. A. Warnier, *Pharm. Weekblad* **13** (1899).

soluble coffee. The residue, which is saturated with water (about 70%), is difficult to handle without first drying. (The extracted coffee residue is called coffee pulp or coffee grounds by various authors.) Table X gives some data on the composition of coffee beans and coffee residue, or grounds. Lyman *et al.* (*23*) carried out amino acid analyses on dried coffee pulp containing 10.6% crude protein with results as shown in

Table XI. In addition to the possible protein value of the dried coffee residue, it contains about 22% oil and 1 to 2% of a waxy material.

Coffee residue has been used on occasion as a cattle food. Mather and Apgar (*26*) found that it could be used as a feed for dairy cattle in a concentration as high as 18% (24% when mixed with molasses) with no significant effect on milk production, butter fat percentage, pulse rate or flavor of milk. Body weight of cows on coffee, however, was significantly reduced.

TABLE XI

AMINO ACID CONTENT OF COFFEE PULP[a]

| Amino acid | In pulp | In crude protein[b] |
|---|---|---|
| | % | % |
| Arginine | 0.38 | 3.68 |
| Histidine | 0.21 | 1.98 |
| Isoleucine | 0.40 | 3.78 |
| Leucine | 0.58 | 5.48 |
| Lysine | 0.36 | 3.40 |
| Methionine | 0.28 | 2.64 |
| Phenylalanine | 0.33 | 3.12 |
| Threonine | 0.33 | 3.12 |
| Tryptophan | 0.10 | 0.94 |
| Valine | 0.50 | 4.72 |
| Crude protein | 10.59 | |

[a] C. M. Lyman, K. A. Kuiken, and F. Hale, *J. Agr. Food Chem.* **4**, 1008 (1956).
[b] Calculated on the basis of 16% nitrogen.

### 5. Cocoa Residues

The by-products of cocoa and chocolate manufacture are cocoa shells and cocoa germs. Fermented cocoa beans consist of approximately 88 to 90% cotyledons, 0.7% germ, and between 10 and 11% shell (*27*).

Processing of cocoa beans involves a separation of the bean constituents into nibs (cotyledons) and shells. The nib portion is further fractionated to remove the germ. It is the germ-free nib which is milled and processed into cocoa and chocolate. Under practical conditions separation is incomplete; hence the shells usually contain ½ to 1% nibs, and the germs, 10 to 25% nibs. Owing to incomplete separation, commercially available cocoa shells contain about 5% or more fat and the germs about 5 to 10% fat. The composition of nibs, shells, and germs is given in Table XII.

Cocoa shells are unsuitable for human consumption because of the high content of fiber; neither are they used to any large extent as a

TABLE XII

COMPOSITION OF COCOA NIBS, SHELLS, AND GERMS

| Constituent | Fraction of cocoa bean | | | |
|---|---|---|---|---|
| | Nibs[a] | Shells[a,b] | | Germs[a] |
| | % | % | | % |
| Moisture | 5.0 | 11.0 | 3.8 | 7.0 |
| Fat | 53.3 | 3.0 | 3.4 | 3.5 |
| Crude protein[c] | 13.4 | 16.0 | 14.1 | 30.5 |
| Tannins | 5.8 | 9.0 | 5.1 | — |
| Crude fiber | 2.6 | 16.5 | 18.6 | 2.9 |
| Ash | 2.8 | 6.5 | 8.1 | 6.5 |
| Pentosans | 1.5 | 6.0 | 7.1 | — |
| Theobromine | 1.4 | 0.7 | 1.3 | 3.0 |

[a] Taken from the following: A. Beythien and P. Pannwitz, *Z. Nahr. Genussm.* **46**, 223 (1923); F. Hartel, *ibid.* **47**, 264 (1924); H. Fincke, *ibid.* **50**, 205 (1925).
[b] From A. W. Knapp and K. Churchman, *Chem. & Ind.* (*London*) p. 29 (1937).
[c] Nitrogen × 6.25.

cattle feed. Only part of the nitrogen is available as digestible protein, about 7% of the weight of the shells. Shells contain a considerable amount of vitamin D; it has been claimed that their inclusion in dairy feed increases the vitamin D content of the milk (*28*).

Some animals, especially horses, seem to be sensitive to the theobromine (3,7-dimethylxanthine) in the shells. In Germany, some deaths were reported of horses, cows, and hogs due to intake of shells. Moreover their ingestion seems to cause constipation; hence the shells are usually mixed with 10 to 15% molasses.

The Ministry of Food and the Ministry of Agriculture in Great Britain issued the following statement in 1943 (*29*):

> Cocoa and chocolate residues including shell are suitable for feeding to adult cattle provided that the daily ration does not exceed 2 lbs. of this material.
>
> In the case of pigs, poultry and calves they are detrimental and the cumulative effect may be serious. Cocoa residues are sold for inclusion in cattle feeds to the extent of 2.5% for feeding to adult cattle only.

Weniger *et al.* state that cocoa shells can be given safely as bulk food to cows in quantities up to 2 or 3 kg. daily (*30*). In actual practice hardly any is used for feed either in the United States or Europe. Use of cocoa shells as fodder has been reviewed by Sperling (*31*).

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